influences outcomes; however, we think that its effects in this situation are minimal as we had performed more than 400 fenestrated repairs alone before the first staged procedure (meaning that technical improvements were unlikely to be relevant), and the principles of multimodal optimization of spinal perfusion were fully embedded in out institution by 2008, as described in our previous publication (meaning that there were no ancillary anesthetic or perioperative measures instituted that would account for the improvement in outcome with staged repair).[8] A related confounder is that of selection bias, the more extensive type II repairs being selected for staging, which is reflected in the increased proportion of aorta excluded in the two-stage group. However, the bias in this case would serve only to heighten the risk with staging, making the lower spinal ischemia rate associated with this technique all the more encouraging.

CONCLUSIONS

Staged repair appears both to protect against SCI and to enhance overall survival in extensive aortic repair.

AUTHOR CONTRIBUTIONS

Conception and design: AO, TM, ME
Analysis and interpretation: AO, ME
Data collection: AO
Writing the article: AO, ME
Critical revision of the article: AO, TM, ME
Final approval of the article: AO, TM, ME
Statistical analysis: AO
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Overall responsibility: ME

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DISCUSSION

Dr Julie Ann Freischlag (*Sacramento, Calif*). I have one initial question. Did you have patients that were scheduled to have this two stage repair, you did the first stage, and for whatever reason they never came back to the second? Did you lose any to death or other issues between the two stages that were not included in your review?

Dr Adrian O'Callaghan. No patient failed to return for the second stage. Two patients suffered a rupture in the intervening period. One of those patients, unfortunately, expired; and the second patient had a successful open repair followed by a successful fenestrated endovascular aortic aneurysm repair.

Dr Freischlag. Did that change your interval thoughts, or are you still doing the same amount of time?

Dr O'Callaghan. There is about a 6 to 12 week lag before we get the fenestrated device designed and ready, so our practice, when we decide to undertake a staged repair, is to perform the thoracic endograft as soon as feasible, and in the meantime we are ordering and constructing the customized fenestrated device.

Dr William Quinones Baldrich (*Los Angeles, Calif*). Very nice presentation and analysis of a large experience. These results support my impression that staging reduces the risk of paraplegia. Interval rupture is a well-documented risk. Is there any particular morphology of the aneurysm that would make you want to repair it in one stage or reduce the time between stages?

Dr O'Callaghan. Well, clearly, symptomatic patients deserve an early repair. And as off the shelf devices become more feasible, then the interval between the staged repairs will again become shorter.

We know from experimental evidence by Dr Etz's group that the time for collateralization is approximately 5 to 7 days. So in terms of how long we need to leave this, I would say 2 to 3 weeks may be optimum; but I don't think anyone knows the exact answer to that question.

Dr Amy Reed (*Hershey, Pa*). You touched early on in the presentation about the length of time for collateralization. You mentioned 6 to 12 weeks. Could you glean anything from the data that you had as to the time frame of how long to wait? If we wait longer, is it better, do patients develop more collateralization? That would be assumed.

And then also as far as the extent of where you covered the thoracic aorta, did you plan to stop at a certain level? Did you always stop before T10? What was your choice for that?

Dr O'Callaghan. When we implant a thoracic device, we're cognizant of leaving enough seal room for the fenestrated component and balancing that with the need to cover enough aorta to stimulate collateralization.

As to the time to collateralization, I don't think anyone knows the answer to that question. The numbers are too small and the times are too heterogeneous to derive any ideal time. I suspect that the time to collateralization may be much shorter than 6 to 12 weeks. Unfortunately, because of the nature of customized devices, there is a 6 to 12 week lag and that, to an extent, determines our present time delay.

Dr Thomas Lindsay (*Toronto, Ontario, Canada*). I'd like to congratulate the authors as well. I think this is a very seminal piece of work.

I have a couple of questions:

First of all, we know that when you do a two staged procedure, the first surgical stage really doesn't take very long for the thoracic piece. What do you think is most important, the influence of the length of that surgery vs the length of time it takes to put in a whole device, including the thoracic piece and the custom?

The second question you didn't mention is temporary paraplegia. And as you know, many of these patients have temporary paraparesis treated with elevating the blood pressure and spinal cord drainage. And you didn't touch on the evidence, or the incidence of that, in both of those and maybe you could tell us a little bit about that.

And then what sort of spinal cord protocol have you been following for those with temporary paraparesis, and did you see more in the first stage or did you see more in the second stage?

Dr O'Callaghan. We saw one case of temporary paraplegia following the first stage. When we see weakness following the operation, we endeavor to raise the mean arterial pressure over 100 mm Hg, and we try and drop the spinal pressure at 10 or below to try and alleviate that ischemia.

And in terms then of the paresis, approximately one fifth of the patients in the single stage group developed permanent paraplegia, the rest resolved. And all the cases in the two stage group completely resolved.

And those mirror Dr Eagleton's publication last year on our complete experience across our entire population of fenestrated and branched patients.

Dr Ian Loftus (*London, United Kingdom*). Just to press on Tom's point, was there a difference in spinal drain protection protocol between those undergoing a single stage and those undergoing the second stage of their staged repair, or are they managed identically?

Dr O'Callaghan. That was one of the reasons why we chose a relatively contemporary cohort of patients. In the period we chose, 2008 onwards, there have been no significant changes in terms of our algorithm. All the patients have a spinal drain inserted preoperatively. The spinal drain is set at 10 intraoperatively and maintained at that point for 2 days; unless the patient develops ischemia, at which point the spinal drain is lowered and the mean arterial pressure is raised. And there is absolutely no difference in terms of how we manage these patients intraoperatively or postoperatively.

Dr Stephan Haulon (*Lille, France*). I try to stage as much as possible also my type II endo repairs. The issue is to find a sealing zone in the middle of the descending thoracic aorta. In most of the patients, we don't find it because the largest diameter endografts we have today are 46 mm. Do you think we should design a new type of endograft just for those two staged procedures?

Dr O'Callaghan. I think when you look into the experimental work on this, these patients need some kind of an ischemic stress. So designing an endograft that would lead to a threshold of ischemia without causing complete paralysis seems intuitive. However, in our experience using commercial devices, we still find a benefit to staging.

Dr Timothy A. Chuter (*San Francisco, Calif*). I wonder about the potential for selection bias. How did you select the patients for the different approaches?

I would also like to comment on the nature of the two stage procedure whereby you're hoping for some aneurysm thrombosis, as a stimulus to collateral formation, but not too much, and you can't really predict which it's going to be. You're left with two general anesthetics, two spinal drain insertions, and all the associated morbidity without a predictable benefit. Have you considered the use of a "perfusion-preserving cuff"?

Dr O'Callaghan. Dr Ivancic has published on his perfusion preservation cuff on a series of 10 patients, and they found three of those patients developed at least transient ischemia, which is a rate of 30%. I mean, I think there are many ways to elicit this stress response and there probably is no ideal method. Certainly, in our experience, staging makes a lot of sense. To complete a complete type II endovascular repair, it takes a number of hours, and so anything that you can do to try and reduce that again would seem to make intuitive sense, without having direct evidence for it.

In the earlier years, we were staging less patients and performing more of them as a single stage. However, in the last 3 years, most of our type II repairs are staged. So there is a bias in that respect. But you saw from our results that the two stage patients have significantly more of the aorta covered by the endovascular device, and therefore they would theoretically increase risk of spinal cord ischemia. Nonetheless, they experienced increased survival and reduced overall rates of ischemia. The perioperative management algorithm has not changed since 2008.

Have we got everything correct? I don't think so. We're still getting some rates of paresis. I think that probably relates to your question about how much of the aorta we covered and what kind of stress response we do elicit. We have no control

over that. I think until some way is devised of controlling for how much of the artery we cover in one cohort, we know how much we can safely cover, I don't think that question can be answered correctly.

Dr Jan Blankensteijn (*Amsterdam, Netherlands*). Just a quick practical question. Do you use a certain length of coverage as a threshold to determine in your current practice to stage the procedure, or not?

Dr O'Callaghan. No, we have no fixed number. From the EUROSTAR data, a length of 200 cm would seem to indicate that that's one threshold. So again, that might be a number you have in your head. But overall when we do the staged procedure, we have the overall repair in mind and we are very cognizant of leaving enough thoracic endograft so that we can safely dock our custom device into it and achieve a durable seal between devices.